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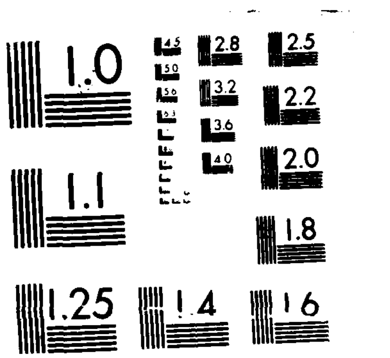

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RESEARCH MEMORANDUM

CURRENT COST ANALYSIS PRACTICE IN THE NAVY – ESTIMATING THE EFFECTS OF COMPETITION

Robert M. Berg
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CURRENT COST ANALYSIS PRACTICE IN THE NAVY – ESTIMATING THE EFFECTS OF COMPETITION

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INTRODUCTION

The work reported in this paper was part of the continuing CNA project to study competition in Navy research, development, and acquisition. The specific project task was to perform a critical review of existing models and cost-estimating methodologies, particularly their logical structure and adequacy in addressing issues related to the potential advantages of competition in contracting. A previous CNA paper [1] discussed techniques of cost analysis found in the literature, particularly those for competitive procurements. This paper evaluates the current Navy practice for assessing the cost effects of production competition in programs using dual production sources. It first presents practices of weapon system cost analysis as a baseline, then discusses particular techniques used when two production sources are expected. The scope of this investigation is limited to cost analysis in the three hardware systems commands--Naval Air Systems Command (NAVAIR), Naval Sea Systems Command (NAVSEA), and Space and Naval Warfare Systems Command (SPAWAR)--and in the Office of the Chief of Naval Operations (OPNAV).[1]

The principal tasks performed by these cost analysis groups are:

- Preparing program estimates for planning, programming, and budgeting
- Preparing life-cycle/design-to-cost estimates
- Supporting proposal evaluations and contract negotiations
- Analyzing contractor performance
- Performing critical reviews of estimates prepared by other organizations
- Preparing independent cost estimates.

The emphasis placed on tasks varies from group to group, in some cases significantly. Appendix A presents more detailed discussions of the organizations, functions, and resources.

The purpose of this paper is to present the weapon system cost analysis practices of each group as a baseline, followed by discussion of particular techniques to assess the cost effects of production competition in programs using two or more production sources.

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1. The OPNAV cost group preceded the Naval Center for Cost Analysis, which was formed in October 1985. The new center brings people previously assigned to the Naval Material Command cost group together with those assigned to OPNAV.

Two types of competition must be distinguished: winner-take-all and dual source. In winner-take-all, the winning contractor receives the total award. This technique has been applied successfully to multi-year procurement of equipment having relatively low technical complexity. Acquisition professionals generally agree that when so used, it reduces cost; however, for highly complex items such as a missile guidance and control section, the investment required by additional manufacturers to attain a production capability makes winner-take-all an inappropriate acquisition strategy. Hence dual sourcing, using annual competition between two firms to determine their relative shares of the production buy, is favored for procuring complex hardware. The central focus of the project task is to evaluate the methodologies used to estimate the cost effects of dual-source competition. Research questions that are suggested by this task include:

- How is cost estimating done by the various Navy cost analysis groups for sole-source procurements? This can be called the baseline cost estimating technique.

- How do these cost groups extend their analysis of the cost of a sole-source program to include the effects of competition when two (or more) manufacturers build the system or equipment?

- How good are these techniques from a theoretical viewpoint, and how can they be improved?

In addressing these questions, this paper will present information that will indicate the state of cost analysis in the Navy, particularly the problems associated with compiling accurate estimates. That background will lead to the appraisal of the ability of Navy analysts to accommodate the additional complexity of cost estimating when there are two production sources for a system or equipment.

No single, simple set of data characterizes the cost analysis capabilities or processes within the Navy. Hence, interviews with Navy cost analysts formed the principal source of data for this paper. Twenty-four such interviews were conducted with approximately 28 analysts. The interviews were supplemented by copies of briefings that summarized organizational missions and cost analysis methodologies. To encourage candor, the interviews were not for attribution. An additional interview was conducted with a systems command contracting officer to obtain a typical contracting officer's view of cost and price analysis. Finally, an interview was conducted in the Cost Analysis Improvement Group (CAIG) of the Office of the Secretary of Defense to determine the state of data base development within the Department of Defense (DOD).

In addition to the interviews directed to the cost analysis community, the research base also includes information gathered during

previous work to assess competition within the Navy. This information was gathered by CNA during a review of 36 competitive and noncompetitive acquisition programs.

COST-ESTIMATING METHODOLOGY--AN OVERVIEW

A survey of current cost-estimating methods was taken as a baseline for comparision with contemporary methods for estimating the cost effects of dual-source production programs. One characterization of the cost-estimating process is that the analyst's task is to (1) take historical data on what systems did cost, (2) combine the theory and understanding of why the elements of cost emerged with programmatic and technical variables of the new system, and (3) forecast what new systems will cost. The historical numbers do not reveal information about unique program activity at the time the costs were being incurred--for example, engineering changes, production problems, contractor business strategy, government motivation, cost control emphasis, and government/contractor relationship. The attempt to forecast what a new system or new equipment will cost is subject to many assumptions: Some, such as total quantity or contract types, are specified by officials at the program level or higher; some are determined by the analyst.

Cost analysts observe, and try to understand, costing in industries in which economic and technological conditions vary widely and in which techniques appropriate for estimating the cost of one type of system or equipment may be wholly inappropriate for another. The analyst who attempts to forecast the cost of a new electronics or avionics system usually must cope with new technology for which little production history exists. A parallel problem occurs in estimating the cost of installing a new electronics system in an existing platform. Each installation tends to be unique, and available historical cost data may simply not apply to a current estimating problem. The ship cost analyst must consider the intense competitive effects brought on in an industry in severe, possibly permanent, recession in which capacity today is abundant but will be reduced in the future as firms leave the marketplace. These realities highlight the amount of judgment, intuition, and skill that the analyst must bring to the estimating process and should be considered by decision-makers as they use cost estimates as one factor in the decision-making process.

Figure 1 presents the principal estimating methods used by the Navy cost analysis groups. Further details and examples are presented in sections that follow. Explanations of the three classical techniques--statistical cost-estimating relationships (CERs), analogy, and engineering build-up--are contained in [2 and 3] and will not be repeated here. The method chosen for a given estimate reflects the purpose of the estimate and the data and time available to make the estimate. Again, the primary interest here is in the methods used to estimate the major systems and the extension of traditional methods to the dual-source production case.

	NAVAIR	NAVSEA	SPAWAR	OPNAV
Parametric: statistical cost-estimating relationships (CERs)	√			√
Analogy	√	√		√
Projection of actual costs (learning curves)	√	√	√	√
Engineering build-up			√	

FIG. 1: PRINCIPAL METHODOLOGIES USED BY NAVY COST ANALYSIS GROUPS

NAVAIR Method

NAVAIR uses different techniques to perform the full range of cost analysis and estimating functions. However, for estimating the cost of weapon systems, the principal tool used by NAVAIR analysts is statistical cost-estimating relationships (CERs). The CERs are uniquely derived for each case, using parametric variables such as speed, power, weight, and thrust. According to [4], the cost strata for multivariate linear regressions are the following:

- Engineering labor hours
- Manufacturing labor hours
- Quality control labor hours
- Special tooling and test equipment
- Sustaining tooling
- Material cost

- Labor/overhead rates

- Purchased equipment.

The data base used to estimate costs of a tactical airplane, for example, may include cost history from a broad sample of similar airplanes; currently the sample could include the T-38, A-4, A-6, A-10, S-3, A-5, AV-8B, F-4, and F-15. Analogy with historical costs of like components of existing systems may be used as a rough check on the parametric estimate of costs of portions of major systems, but such a technique requires particularly keen judgment by the analyst to ensure its validity. For airplanes, the government may furnish a significant amount of equipment--such as radios, navigation instruments, external fuel tanks, and ECM--to the contractor to install in the airplane during manufacture. Learning (or cost improvement) curves developed from actual production history are used to estimate the costs of these components. Typically, the cost of the 100th unit is built up from the component strata costs, and learning curve theory is then applied to forecast total program costs. Figure 2 illustrates this build-up of stratified costs to generate a total program estimate.

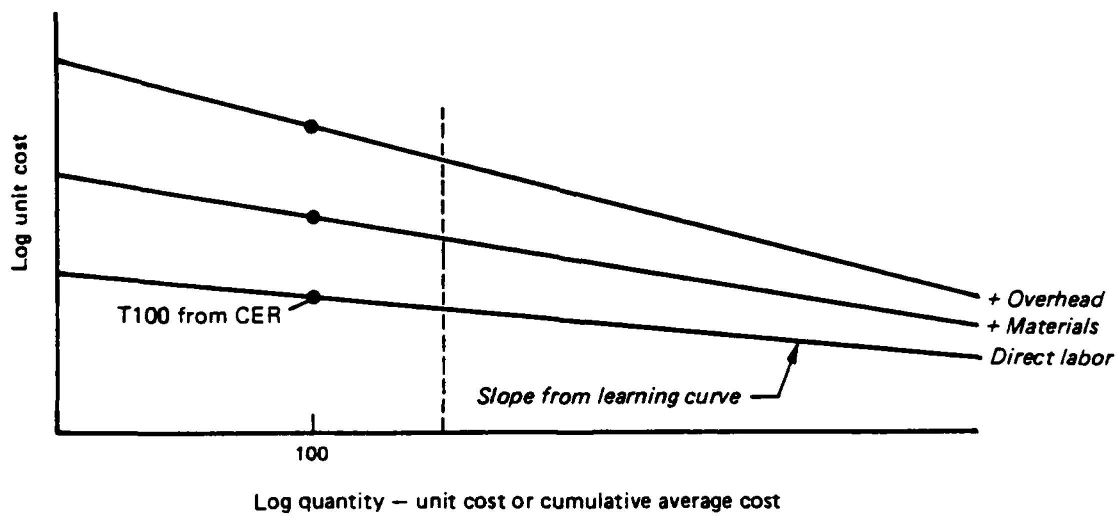

FIG. 2: STRATIFIED COST BUILD-UP TO PROGRAM COST

The NAVAIR estimate for the T-45 Training System illustrates how each estimate is treated as a separate case that deserves careful use of available historical data and information about the program. Standard statistical CERs were used, but they were developed to incorporate the effects of the airframe's prior history as the British Aerospace Corporation (BAe) Hawk trainer. This meant using cost history for the Hawk and estimating separate costs for the portions of the airplane to be built by BAe and Douglas Division (DAC) of McDonnell Douglas Corporation. Other considerations included adjustments for airframe portions common to the Hawk but planned to be built by DAC rather than BAe, and totally new system requirements for which no Hawk history existed. Other useful data that aided the estimating process were design and production cost histories for DAC on the A-4 (like the T-45, a subsonic carrier-capable light jet airplane) and for MacDonnell Aircraft on the AV-8B (like the T-45, a U.S.-produced derivative of a British airplane). CERs were built up to forecast both development and production costs.

Following is an illustration of how a CER was used to forecast one element of development cost: the total contractor labor devoted to the flight test phase. The CER (which was based on data from A-6, A-10, S-3, A-5, E-2, F-4, F-14, F-15, and F-104) was:

$$\text{Labor hours} = 0.004552(We)^{0.87028}(Vmax)^{0.65309} ,$$

where

We = weight empty (pounds)
Vmax = max speed at altitude (knots).

The estimate of 735,965 hours was reduced by 4.9 percent by subtracting out other labor (quality control and manufacturing), based on A-4 history. It was also decreased to reflect differences between the planned contractor flight-test hours and the data-base flight-test hours, using a learning curve relationship between design-engineering hours and flight-test labor hours. The final revised estimate of 494,589 labor hours was then allocated between BAe and DAC according to each firm's planned participation.

NAVSEA Method

The Naval Sea Systems Command (NAVSEA) emphasizes knowledge of industry costs and capacity and recent shipbuilding cost history to develop estimates for the costs of ships. CERs are used, but they are relatively simple measures of the cost to perform the tasks involved in shipbuilding--direct labor hours per ton, for example--and are generally not derived with rigorous statistical techniques.

Fundamental questions to be answered are "How many hours will it take to build this ship?" and "What labor rates should be used to

project the total cost?" To answer these questions for the lead ship of a class, the analyst begins with relationships based on the design of the ship. For example, the estimate of labor hours per ton is developed from the best information available for the portion of the ship being built. If possible, analogies and engineering cost build-ups are used for specific ship portions, such as power-plant and auxiliary equipment that already exists in similar form on other ships. The basic construction cost of the ship is built up from three-digit-level cost categories to the one-digit-level categories depicted in the NAVSEA ship work breakdown structure (SWBS), presented in table 1. In forecasting the labor rates, an assumption is made about where the ship is likely to be built--in which yard, or in some cases, on which coast. Government-furnished material (GFM) estimates are provided by other managers within NAVSEA as well as other systems commands. These estimates are often performed using parametric analysis, frequently by support contractors. The analyst works with the managers who submit these estimates (excepting those for nuclear components) to arrive at final figures to be incorporated into the overall ship estimate. For subsequent or "follow" ships of a class, the same technique is used, except that the accuracy of the estimate should improve as actual cost data becomes available from construction of the lead or other earlier ships.

TABLE 1

NAVSEA SHIP WORK BREAKDOWN STRUCTURE

Cost group	Identification
100	Hull structure
200	Propulsion plant
300	Electric plant
400	Command and surveillance
500	Auxiliary systems
600	Outfit and furnishings
700	Armament
800	Integration/engineering
900	Ship assembly and support services

SOURCE: Naval Sea Systems Command presentation, "Cost Estimating and Analysis Division," 28 Jan 1985.

Each shipbuilding contract contains a compensation adjustment clause allowing the target price of the ship to change during construction in accordance with current Bureau of Labor Statistics escalation indices. The costs subject to escalation are estimated using the

OSD/OMB escalation index. The composite cost for the lead ship then emerges as the sum of basic construction costs from the SWBS categories, GFM estimates, projected contract escalation, and other miscellaneous costs.

The unique aspect of an estimate produced at NAVSEA is that it usually pertains to a specific yard: The cost analyst first receives estimates of the labor and material needed to fabricate the ship, then meets with the NAVSEA group that forecasts workload in the various yards serving the Navy and attempts to determine which shipyard will likely be contracted to build a particular ship. Knowing probable yard costs and expected labor escalation costs (based on known labor agreements) permits the total estimate to be developed.

SPAWAR Method

The task of the Space and Naval Warfare Systems Command (SPAWAR) cost group is very different from that of the other systems commands. Its role is to establish the government's negotiating position for production contracts and to assess the cost realism of development proposals. It is not staffed to support the entire command to the extent that cost groups in NAVAIR and NAVSEA do.

SPAWAR analysts perform detailed, on-site fact finding at contractor plants. They typically develop a range of estimates--pessimistic, most likely, and optimistic. The estimates are made using an engineering build-up technique from a detailed work breakdown structure. Data are maintained on cost histories at 80 contractors within the electronics industry; these data provide a base from which the detailed cost estimates can be made and compared to contractor proposals for reasonableness and realism. The SPAWAR cost group does little program cost estimating for programming and budgeting purposes, and individual projects usually rely on support contractors for this function.

OPNAV Method

The primary tasks of the OPNAV cost estimators are to review the program cost estimates of the systems commands and make independent estimates to assess the reasonableness of the program cost estimate; thus, they approach cost estimation somewhat differently. OPNAV analysts typically use parametric models at a more aggregated level than those used in the systems commands. Most are developed in-house, some are developed by private firms under contract, and others are published in the open literature by organizations like Rand. The OPNAV analysts necessarily work at a more aggregated level because the program-to-analyst ratio is much higher than in the systems commands.

An example is the following cost-estimating relationship for estimating manufacturing manhours for an airframe:

$$mmh = 0.4639(mp)^{-.2802}(r)^{-.1446}(w)^{.7239} \quad ,$$

where

mmh = manufacturing manhours
r = annual production rate
w = lot weight
mp = production lot midpoint.

The analyst typically adjusts the model to reflect the characteristics of the problem at hand or to incorporate knowledge not available when the model was generated. Figure 3 portrays an example of such an adjustment. The problem was to estimate nonrecurring engineering labor hours required in research and development of a new airframe. While the available cost-estimating relationship was sound, its data base was old and did not separate recurring from nonrecurring hours or divide nonrecurring engineering hours between airframe and system engineering/project management. In this instance, good current data were available on the actual hours that were needed to develop an airframe similar to the one being costed. The estimate was made by "calibrating the CER" using the analogous data--in effect, using the data to adjust the coefficients of the CER without changing the weight exponent, to make the estimate of the desired number of hours. Here, judgment was used to attempt to improve the quality of the estimate. An alternative approach would use a more current CER that embodies some statistical validation. Updating CERs requires continuous, time-consuming investment and is undertaken in OPNAV as resources are available.

Escalation Indices

Cost estimating requires knowledge of economic escalation because equipment development and purchases are spread over several years. Inflation indices published by the Office of Management and Budget (OMB) and the Office of the Secretary of Defense (OSD) are typically used to put costs into constant-year dollars for budgeting and estimating purposes. Both NAVAIR and NAVSEA believe the OSD/OMB indices lack the accuracy needed for near-term estimating purposes, and have developed their own. The OSD/OMB indices are developed from a forecast of the GNP deflators made by the Council of Economic Advisors and are considered by NAVAIR and NAVSEA to be less accurate for their particular material and labor categories than indices they have developed and maintain in-house.

NAVAIR Indices

NAVAIR developed its indices to improve the accuracy with which it puts actual historical costs into constant-year dollars. This should

allow better estimates of the year-to-year changes in historical costs, which in turn should improve the precision of derived learning curves. Additionally, the indices permit a better forecast of inflation-driven cost growth in the future than would be possible using the OSD/OMB indices.

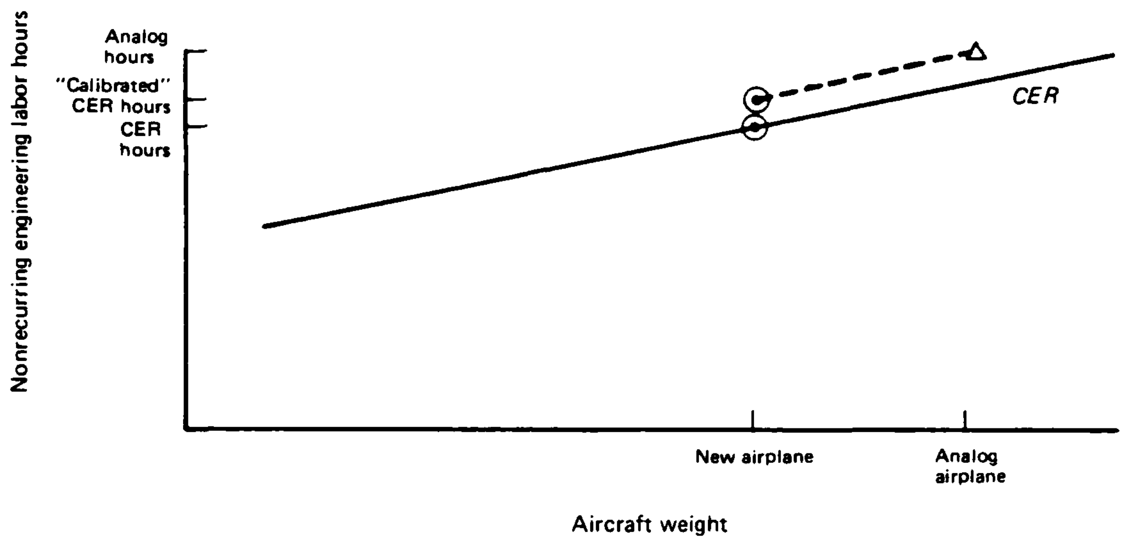

FIG. 3: "CALIBRATION" OF COST-ESTIMATING RELATIONSHIPS (CERs)

Analysts in NAVAIR's Research and Methods Section first studied historical cost data to determine the actual labor, material, and overhead content of the various cost categories that make up total system cost. They then developed composite labor indices from weighted averages of applicable wage and salary data obtained from the Bureau of Labor Statistics (BLS). Similarly, content-weighted indices of raw material costs were calculated, using producer price indices that most closely represented raw material used in aircraft manufacture. Overhead indices were computed by sampling contractor overhead data and computing a weighted overhead average. A Data Resources Incorporated (DRI) econometric forecasting model was used to project the stratified component costs into the future and compute projected escalation indices. Although DOD does not permit these in-house indices to be used for developing program estimates or budgets, the indices should provide Navy

acquisition managers with an improved forewarning of potential effects of inflation on program cost.

NAVSEA Indices

NAVSEA prepares its own escalation indices to improve its ability to forecast ship prices for budgeting and contract negotiating purposes. Analysts compute a weighted average wage rate across 19 shipyards, then develop escalation indices by applying knowledge of the impact of existing labor agreements on these wage rates. Historically, steel prices have been shown to correlate well with aggregate material prices, and a forecast of steel prices is used together with a linear regression of past steel and material data to produce a material index. The NAVSEA-produced indices are used to escalate basic shipbuilding construction costs for the budget year of the Program Objective Memorandum (POM) (the only case in which a defense procuring agency's in-house estimates are permitted to be used), while OSD/OMB indices are used for the out years. Contract escalation, GFM, and other-than-shipbuilders' costs are adjusted using OSD/OMB inflation indices.

Estimating Cost Effects of Dual Sourcing

The renewed emphasis on competition in weapon system acquisition, particularly competition between two manufacturers during production, has increased the need for methods to estimate its cost effects. These effects must be considered in selecting and defending the acquisition strategy, and in preparing estimates of the program cost. Although competitive dual-source production for aircraft has not been used since World War II, the acquisition strategy for the V-22 Osprey airplane now requires estimation of such effects. While it is not unusual for ships to be built in competing yards, only recently have dramatic competitive effects become apparent, as will be discussed later.

Weapons and Aircraft

The conceptual methods used by Navy analysts to estimate costs of weapons that are dual sourced generally reflect the methods reported in the literature, as discussed in [1]. The introduction of the competitive second production source is typically modeled by a downward shift in the learning curve of the existing source, together with a rotation (or steepening) of the curve. (Not all researchers, however, agree that such a phenomenon truly exists.) Navy analysts work at the component cost level and build up to the price level if data are available. Data at the functional cost level are available to the government for very few dual-sourced systems. Most examples of dual sourcing cost analyses have been in air-launched weapons, and consequently NAVAIR and OPNAV analysts have had the most experience in using the technique.

When using this shift-and-rotation model to construct a dual-source analysis, cost analysts in the past usually used parameters obtained

from the Sparrow/AIM-7F air-to-air missile. Values for shift and/or rotation, together with expected l ng-term learning curve slopes, were estimated, based on historical cost data from Sparrow, which was built competitively by the Raytheon Company and the General Dynamics Corporation. For example, to estimate the effects of dual sourcing the Phoenix/AIM-54C missile at Hughes Aircraft Company and a competitor, to be chosen, NAVAIR analysts first assumed a baseline price improvement curve (PIC) slope based on sole-source procurement, adjusted for production rate, and based on the not-to-exceed estimate for the FY 1985 planned production at Hughes. Starting with the fiscal year in which the second source would begin to build its first competitive AIM-54C, the Hughes PIC was shifted downward and steepened; 2 years later, it was steepened again. For the second source, the departure point for the PIC was the expected Hughes FY 1985 not-to-exceed estimate. A PIC was generated, displaced substantially downward to yield the initial competitive price, and subsequently adjusted for price and rate effects, using the AIM-7F experience. That experience base is now being expanded, according to NAVAIR analysts, and the estimate of AIM-54 cost has been refined as more data have become available.

The only aircraft program that has been a candidate for dual sourcing in recent years is the V-22 tilt-wing Osprey. Baseline estimating of Osprey costs is difficult because 57 percent of the structural weight is expected to be in composites, for which there is little history. The assumptions required to estimate the effects of dual sourcing included a split of the buy between the winner and loser, shift and rotation of the PICs for recurring purchased equipment and recurring manufacturing hours, and changed profit levels for the winners and losers of the yearly competitions [5].

OPNAV analysts pursue essentially the same techniques to estimate independently the effects of dual sourcing of aircraft and missile weapons systems, again using Sparrow/AIM-7F production as the primary historical model. First-source cost is assumed to take a drop in the initial year of competition, although profit may be increased or decreased, depending on the situation. Subsequently, cost stays on a constant learning curve, but profit is gradually reduced with each production buy to some minimum level. The cost of the second source's first competitively built unit is typically presumed to be less than the cost of the identically numbered unit of the first source. This ost is estimated by taking into consideration the number of units built by both sources and the second source's position on the learning curve. Rate adjustment factors are applied to give a slightly lower cost to the source having the higher percentage of yearly units, and the learning curve slopes are adjusted to bring the prices together for the same quantity built by either manufacturer by about the fourth competitive buy.

Ships

The first substantial effects of competition seen in shipbuilding in recent history occurred in proposals received for ships in FY 1984. Some competitive bids were much less than budget estimates had been. The low prices reflect not only the effects of the Navy's production competition policies but also the worldwide decline in shipbuilding and a significant, unforeseen lessening of inflation.

Ship cost estimates are based on recent bid and cost history. The empirical analysis of longer term historical data typically used for weapons is not generally used for shipbuilding. The results of such analysis would be less relevant and useful because the economic changes now occurring in the industry would override conclusions derived from history. Because ship costing is done by using recent cost history as the most relevant data, projected prices of future ships procured competitively are now being estimated by baselining costs to the lowest-cost yard in a given competition and adjusting forecast profits to reflect levels found in recent bids. The NAVSEA cost group appears to have gained substantial experience from the claims period of the mid-to-late 1970s and the impact of competition in a declining industry seen in the FY 1984 bids. This experience can be applied to estimating competitive ship prices. However, the uncertainties introduced by contractor pricing strategies designed for survival of the firm in today's competitive and shrinking market will continue to complicate competitive ship cost estimating.

Navy policy is to build ships competitively in multiple yards whenever possible, based on considerations for the industrial base and hull delivery schedule. Therefore, cost analysis has usually been used as a budgeting tool for ship construction programs rather than as a multiple-source decision tool. It does not appear that there are significant additional costs attributable to this multiple sourcing. Although learning occurs in a given yard as succeeding ships are built, rate effects at one to two ships per yard per year are probably not significant. The investment costs to establish a second shipyard in production are small on a relative basis compared to facilities and tooling/test equipment costs for a second missile contractor. For example, approximately \$75 million was invested in equipment and facilities to prepare General Dynamics to be a second source on Sparrow/AIM-7F, including government in-house and production qualification costs. The cost of the FY 1978 General Dynamics production buy for 750 missiles was approximately \$114 million, indicating that the facilities investment cost is, in order of magnitude, near to the cost of a year's buy of missiles. (Data are in constant FY 1984 dollars.) Conversely, it is generally considered that a follower shipyard can undertake construction of a new class of ships without extensive additional facilities. One analyst stated that the lead yard may spend \$80 to \$100 million for plans for a new ship while the follower yard will spend about one-third this figure. Both are far below the cost of major naval vessels, which is now in the hundreds of millions of dollars.

Finally, it appears to be in the Navy's best interests to continue to split ship awards between shipyards. The Navy appears to have received excellent competitive prices in recent ship awards; declining profit levels have been bid by contractors seeking to remain in business. In a time when orders for new merchant ships are, and are expected to remain, almost nonexistent, dividing the available Navy business among yards is one way to maintain the shipbuilding industrial base.

ISSUES

The issues identified by the study team in this review of Navy cost-estimating practices encompass the broad range of cost estimating, including problems with data, general cost-estimating methodology and methodology for dual-source programs.

These issues need understanding and attention because of their impact on cost-estimating capability and their implications for the quality of budget estimates. In turn, poor budget estimates may affect individual programs as unforeseen cost growth may lead to stretch-out. The stability of the procurement process on several programs may be affected as funds are shifted to programs with unforeseen cost growth.

Data

Historical cost data are the foundation for estimating the costs of future systems. Without good cost data on prior systems, the analyst has no firm point of departure. The problems of acquiring, validating, and using data are probably the most severe faced by the cost analysis community. Most analysts interviewed during this study stated that some manifestation of the data problem was the most troublesome obstacle to developing good estimates.

Analysts have at least three sources of cost data, discussed in the following paragraphs: contractor cost data reports (CCDRs), cost performance reports (CPRs), and data obtained directly by the analyst from contractor sources. While the best data may be obtained when a cost analyst has developed a confidential and trusting relationship with a contractor employee, such an arrangement may preclude making the data available to other analysts. Also, unofficially obtained data are not subject to audit. The existence of these informal channels indicates that the data provided by the formal cost-reporting system are inadequate for the needs of some analysts.

The policy and procedures for acquiring cost data are contained in DOD Instruction 7000.11, which covers CCDRs, and are implemented within the Navy by SECNAV Instruction 7000.20. The genesis of the CCDR was the inability of cost analysts to use data acquired for program management purposes to assess contractor cost proposals for the TFX program in the mid-1960s. The 7000.11 instruction provides four standard formats for

reporting of cost data by contractors. The data are required for designated major system acquisitions and those exceeding $200 million in research and development or $1 billion in procurement costs (constant FY 1980 dollars). Data may also be required on other selected contracts, generally exceeding $2 million. The information was expected to provide the cost analysis community with the details of historical costs experienced on acquisition programs, to a depth adequate to use in estimating future costs of emerging acquisitions. The acquiring organization is required to distribute a CCDR data plan at least 60 days in advance of issuing the RFP for the full-scale development contract. This is to be followed by a meeting of interested persons in the cost analysis community, at which the final plan will be agreed upon.

Another primary source of cost information is the cost performance report (CPR) required by DOD Instruction 7000.10 and published within the Navy by SECNAV Instruction 7000.15. The CPR (and its equivalent for small programs, the cost/schedule status report (CSSR)) is a management tool used on selected major acquisitions whose contracts require compliance with DOD cost/schedule control system criteria. NAVSEA uses it as a standard reporting medium for NAVSEA managers to track the progress of construction of individual ships.

Throughout DOD, compliance with cost data reporting requirements has been uneven. Although CCDR data collection is required by DODI 7000.11, some individual acquisition managers have not complied. Because historical CCDR data are primarily for the use of the cost community and are of little value to program offices, some managers have not ordered the data, and the cost community has been left with an incomplete historical base for use in projecting the costs of future systems. For example, the Army and Air Force do not require cost data reporting on firm-fixed-price (FFP) contracts. However, NAVAIR carefully follows the CCDR/CPR reporting requirements, including reporting on FFP contracts. For its cost data, NAVSEA relies principally on the CPR, as well as proposals, negotiated contracts, monthly material and manhour reports, and direct access through the superintendent of shipbuilding in each yard. It does not rigorously enforce CCDR reporting requirements. (OSD recently protested NAVSEA's lack of compliance with CCDR reporting requirements to the Assistant Secretary of the Navy (Shipbuilding and Logistics), citing 20 programs for which CCDR data plans needed to be submitted and 8 existing programs in which reporting was delinquent [6].) The SPAWAR cost group uses neither the CCDR nor CPR; it prefers to keep its own cost data base on individual contractors, because this system best matches the fact-finding techniques it uses for cost analysis.

Assuming that historical cost data are available to the analyst, a further problem is ensuring that data from different contractors are correct and reflect similar definitions of cost categories. CCDR data are subject to audit and should be accurate, but the audits apparently are not done routinely. Definitions are probably a greater problem, and contractor reports may have to be adjusted to ensure that reported costs

factually represent the same task and material categories across reports from different contractors.

Lack of time to look at data is another problem shared by most analysts. Ideally, analysts would routinely review contractor data reports as they are received to detect cost trends and track actual versus estimated costs. But analysts seldom have time to review fresh cost reports that are not directly related to the estimate currently being developed.

Much of the work in developing methodologies and data bases in support of cost analysis is done in-house, supported by contractors and the research community. The quality of the support work depends on obtaining access to detailed cost data from hardware contractors; yet, the constraints placed by the hardware contractors on distributing this information make access very difficult. This impairs the quality of services provided by these sources.

Navy cost data are not generally maintained in large automated data files that are easily accessible for aggregation across specific programs and categories and amenable to rapid statistical analysis. The NAVAIR cost group is now implementing an automated data base. However, this is the only Navy effort of this type known to be in process. The OSD Cost Analysis Improvement Group (CAIG) is undertaking a similar effort for its total CCDR files, but it does not expect the automated system to be available for 1 to 2 years. Such an undertaking is complex and time consuming. Several efforts to employ contractors to provide an automated data base have failed. Nevertheless, easy access to sound data remains a worthwhile goal that could enhance and streamline the cost analyst's task.

Data problems make the cost analysts' already difficult task more difficult. The quality of new estimates can vary because historical data may be incomplete or reflect different interpretations of cost categories by hardware contractors. The analyst must adjust the data into a consistent base from which to derive the new estimate. Often, this estimate will be of lower quality than needed because critical historical data are not available. OPNAV analysts are particularly dependent on CCDR data that can only be obtained by systems commands' acquisition managers. The problem is most acute in the area of avionics/electronics, where little CCDR data has been obtained, thus compounding the difficulty of making estimates in an area of rapidly changing technology. Analysts are similarly hampered by gaps in cost data on NAVSEA weapons: CCDRs do not exist for the Standard Missile, Mk 46/48 torpedoes, Asroc, or the Tomahawk cruise missile.

General Methodology

Cost estimating today is strongly based on observation and experience with due regard for understanding the underlying theory of systems

and processes. Methodologies remain within the classical categories--statistically derived CERs, engineering build-up, and analogy. Within these categories, especially in the development and use of CERs, methodologies have matured as people, including those skilled in engineering disciplines, and technology have been applied to the problem.

Today's analyst has tools that permit developing more comprehensive models with which to forecast the costs of future acquisitions. Computers represent a revolution in cost-estimating capability, both in the potential for better construction of, and access to, data bases and in the ability to expand the volume of calculations that can be performed. As computational capacity has moved from mainframes through minicomputers to microcomputers, the analyst increasingly has been afforded ready access to immense computing power. He can now explore additional levels of detail and variations in assumptions that were out of reach 5 years ago. The ability to interpret and display results has improved with the generation and presentation capability offered by new graphics software packages.

Notwithstanding problems already discussed, data bases are becoming better in quality, more extensive, and increasingly capable of supporting analyses at a lower level of the work breakdown structure. The analyst still must use the data with great skill, working around gaps and maintaining constant awareness of differences in the ways contractors may report identical elements of cost. The analyst must also carefully interpret historical data, being aware that the data can capture contractor inefficiencies and gaming that might have existed at the time the costs were recorded.

Cost analysis remains an art in which scientific disciplines play a major role. Key to the solution of today's problems is the perceptive analyst who can confront the formulation and construction of the analytic problem. Although analytic techniques are evolving, so are the challenges. New design and production technologies affect the amount and distribution of resources needed to develop and build new systems in ways that may not be well understood. The state of the design art now permits system complexities that require new techniques to estimate future production costs. Continuing effort needs to be applied to developing the cost-estimating methodology required for new weapon system technology. But the procurement system requires estimates now, and the analyst has no choice but to use the tools at hand.

Numerous cost analysts interviewed for this study recognized that contemporary methods of cost analysis need to be augmented with other information to improve estimating accuracy through better understanding of the total environment in which costs are generated. The objective should be to make this information measurable and predictable. Candidate areas for further research include:

- Contractor business strategy; near-term profit vs. long-term return on investment

- Manufacturing capacity and utilization

- Profit analysis

- Contractor decision making under contract uncertainty: number of units to be awarded in dual-source procurement

- Market research as an adjunct to cost modeling

- Analysis of contractor overhead costs/overhead philosophy

- Impact of technology and productivity improvement on cost.

<u>Methodology for Dual-Source Programs</u>

When estimating the cost effects of dual sourcing, the analyst must make numerous assumptions in addition to those required in a sole-source cost estimate. That implies that the dual-source estimating problem is considerably more complex. Consider first the production cost estimate for an item built by one manufacturer. Such estimates always require assumptions, but the quality of the estimate of initial production cost improves once fabrication of test articles starts and actual costs begin to accumulate. The most difficult estimate is probably that required for the milestone II decision by the Secretary of Defense (whether to begin full-scale engineering development). At this point, few actual cost data are available, yet defense decision-makers need good estimates of production costs because an affirmative milestone II decision leads with high probability to an affirmative milestone III decision later.

By the time of the milestone III decision (whether to begin production), a much better estimate of initial production cost can be made. The forecast of total program investment cost (which includes research and development, facility preparation, and production qualification and procurement, and excludes operations and support) remains heavily dependent on the analyst's estimate of the learning curve that will prevail; usually, however, enough data on the firm's past performance exist that the analyst can couple it with actual cost data available and make a reasonable estimate. The principal unknown is whether the planned procurement profile (quantity vs. year) will actually be executed. For example, if the procurement is stretched over additional years, economies of scale may be lost and cost will increase relative to the original estimate.

Sometimes, the results of the cost analysis for a sole-source program will be used to modify the program in terms of system requirements or total production. Only rarely would such an analysis cause a review of the decision to proceed with the program. Conversely, the initial cost analysis of the effects of dual sourcing on program cost is implicitly made to assist in making a <u>major decision</u>: whether to proceed with dual sourcing. (Navy policy [7] is to have dual production sources.)

Therefore, analysis may not affect the decision in the Navy but may have a significant effect on the decision to support the Navy strategy at the OSD and Congressional levels. The dual-source estimate may be critical to the program's ultimate acquisition strategy. Yet this estimate is typically based on less extensive data than are available to make sole-source estimates. It requires selection of assumed performance values for the second contractor, as well as some entirely new assumptions. These assumptions (some of which are program variables specified to the analyst) are the following:

- Values for shift and rotation of the learning curve
- Baseline learning curve
- Initial unit costs
- Rate effects
- Quantity profile by production year
- Year in which competition occurs.

Since the dual-source decision normally precedes selection of the second source (assuming that a source has not been directed), the key missing information is which firm will be the second source. (Before bids are received, all of the interested contractors may not be known for certain.) The historical performance of this firm--learning curves realized on past programs--cannot be factored into the cost estimate. Nor are there any rational data available to predict the initial price of this yet-to-be-named firm's product, another key assumption. Thus, a major decision--whether to have two production sources--hinges upon a cost estimate that is implicitly less accurate than that for a single-source program.

Navy cost analysts have developed methods of predicting the effect of production rate on costs. Typically, it is another variable to estimate from insufficient empirical data. In the dual-source estimate, the effect of rate on cost may be severe because available quantities are split between the two producers and it is logical to presume the loss of economies of scale.

The year in which competition occurs is a particularly critical variable. If actual competition is delayed beyond the assumed production point, the delay puts the second source at a further competitive disadvantage in manufacturing learning. The year during which competition will occur is usually specified to the analyst. One analyst interviewed for this study reflected that good cost estimating involves learning the program and the contractors--visiting them frequently, observing production, talking to engineers and production managers, and hearing problems and solutions. Such an analyst might have personal

views as to when true competition might really occur but is usually bound to use the program assumptions.

Despite the popularity of using data from the Sparrow/AIM-7F program, there is no obvious rationale for doing so. The data were generated in the 1970s for the air-to-air missile. It is questionable whether values for shift-and-rotation effects of competition on the Sparrow/AIM-7F prime contractor's learning curve will apply in acquisitions occurring a decade or more later. Such effects observed in the competitive bids submitted by Raytheon and General Dynamics in the 1970s may not carry over for other firms building systems in the 1980s and 1990s. Additionally, improvements in production technology may have unpredictable effects on the shift-and-rotation phenomenon, if it indeed exists.

Thus the result of an analysis of the impact of dual sourcing on program costs contains even more uncertainty than an estimating of the costs of sole-source acquisitions. An alternative approach to making that uncertainty explicit is to use the learning curve technique to perform a sensitivity analysis to place bounds on the cost effects of dual sourcing for various scenarios. This approach was used to estimate effects of dual sourcing the Standard Missile 2 Block II production program [8]. The analyst first visited the sole-source producer, General Dynamics, to gather detailed cost data, including general and administrative costs, on Standard Missile production. He hypothesized three levels of General Dynamics' performance under sole-source production conditions:

- Least costly: constant decrease in unit missile cost
- Baseline: flattening out of the learning curve from a 78 percent slope to an 85 percent slope after production of 2,500 missiles
- Most costly (business-as-usual): flattening out of the learning curve from a 78 percent slope to a 92 percent slope after production of 2,500 missiles.

The program costs were estimated using these three scenarios. The learning curve values that were assumed were based on (but not identical to) actual General Dynamics production learning curve values.

Next, three conditions of competition were imposed on the program, and the change to the three sole-source estimates for each of the three competitive conditions was computed. The three competitive scenarios can be summarized as follows:

- Pessimistic: Follower lags leader by 2 years after analyzing the technical data package (TDP); no real competition occurs.

- Baseline: Follower lags the leader by 1 year after analyzing TDP; both leader and follower steepen learning curve slopes by 2 percent at onset of competition.

- Optimistic: Follower matches leader's experience (learning) after analyzing TDP; both producers steepen learning curve slopes by 4 percent at onset of competition.

Table 2 presents the results of the analysis. Savings resulting from competition are displayed as positive numbers, in billions of dollars. Note that savings are realized in three of the nine possible outcomes. From these results, the analyst concluded that "The business-as-usual cost can be realistically reduced by as much as 15 percent under a highly aggressive leader/follower approach. A failure of this approach can result in as much as a 20 percent increase in total program cost."

TABLE 2

ESTIMATED IMPACT OF DUAL SOURCING ON COSTS OF STANDARD MISSILE PRODUCTION

Hypothesized performance of General Dynamics under sole-source conditions	Saving/penalty resulting from dual-source production (billions of dollars)		
	Pessimistic scenario	Baseline scenario	Optimistic scenario
Least costly	- 1.20	- .71	- .33
Baseline	- .58	- .09	+ .29
Most costly	- .03	+ .45	+ .83

SOURCE: Cost Analysis Division, Headquarters Naval Material Command, "An Analysis and Estimate of Standard Missile Dual Souce Estimating Costs," by Brian J. Flynn, 7 Dec 1984.

A sensitivity analysis of this nature provides the decision-maker with probable bounds on the cost outcome of a dual-sourcing decision. It is probably the best guide that can be expected, given the available methodology. The analysis also highlights the management skill that the government must apply if a cost saving is to be realized.

Even establishing the probable bounds requires careful selection and application of the assumptions. Here, the analyst had data on analogous missiles (earlier versions of Standard) as a basis for

assuming first unit cost and learning curve slopes for General Dynamics, but he had to assume values for these parameters for the second contractor without knowing its identity or cost history on similar programs. For an even more complete picture, the analysis could have been repeated, using various production profiles in addition to the 26,000-missile procurement spread over 18 years that was used. (A common programmatic change is a stretch-out of production that results in lower quantities for each producer in some years, further diminishing economies of scale.) One of the values of analysis of this sort is that it highlights the assumptions and the sensitivity of the outcome to the assumptions; thus, the decision-maker gains a sense of the fragility of the analysis of cost effects of dual sourcing.

The number of variables and the range of values each variable may take for a typical program stretching over 5-10 years make any point estimate of "savings" or "costs" resulting from dual sourcing nearly meaningless. Indeed, analysts admit that even determining savings from past dual-source programs for which good historical price data are available presents the same difficulty. No good way of estimating the slope(s) of the sole-source producer's learning curve, if sole-source procurement had continued and competition had never been introduced, has ever been determined. Careful sensitivity analysis can illuminate the potential cost effects of dual sourcing, provided assumptions are carefully chosen and explored. The estimates can then be used to place likely bounds on the effect that dual sourcing would have on the budget. But under current methodology, the decision-maker who insists on a point estimate will get a number that is of questionable value.

Parametric or sensitivity analysis methodologies are available and, as the Standard Missile example shows, are sometimes used in making explicit the range of estimated cost outcomes. The problems associated with using these methodologies are the greater analytic resources that they demand and the nonacceptance or misunderstanding of the uncertain estimates by decision-makers and reviewers. One may ask, what is the appropriate point in the decision process at which the uncertain cost estimates are converted by a decision-maker into the point estimate that the acquisition system requires? This is a particularly important question when major strategy alternatives--whether to compete a program, what type of competition to use, and when to implement competition--are being determined.

CONCLUSIONS

The resources applied to cost analysis in the Navy have grown in the past decade in response to pressure for improved cost estimating. Missions of the cost groups have evolved to meet the needs perceived by the individual commands; central direction to Navy cost analysis effort has been limited. (See appendix A for further detail on the groups' organizations, functions, and resources.) NAVAIR and NAVSEA cost groups have added significant numbers of people, including more industrial

engineers in recognition of the need to understand the technical factors that drive cost. The small SPAWAR group may have the best knowledge of the contractor cost structure and industry environment of any Navy cost group. But it has not grown in capability when compared to the other systems commands. The cost groups do not appear to have close working relationships, and opportunities for improved estimating through synergistic effects of shared knowledge and experience do not seem to be exploited. The new Naval Center for Cost Analysis, formed on 1 October 1985 from the previous OPNAV and NAVMAT cost groups, appears to be an organization that can provide leadership and focus to future Navy cost analysis efforts.

Cost-estimating methodology has continued to evolve, aided by computer techniques and the assignment of engineers to analysis tasks. Yet accelerating technology threatens to outrun the evolution of the methodologies, requiring the utmost in innovation, insight, and judgment from the analyst. Technological improvements in electronic design and fabrication, substitution of composite materials for metal in structures, and improved manufacturing methods have created a gap in the historical data base and have made the need for new approaches to cost estimating more acute. A cohesive effort needs to be undertaken to address this problem. This is where creative interchange within the Navy cost community could be valuable. For example, SPAWAR techniques for understanding contractors' cost structures could complement the advanced statistical methods and data base creation at NAVAIR.

More emphasis needs to be placed on looking at the accuracy of past estimates, inquiring into new techniques that complement classical methods, and routinely examining contractor cost data. But confounding this need is the crisis atmosphere in which cost analysts work. They always have new estimates to make and old ones to update. Hence, little time is available for reviewing the process and current cost trends. However, this investment of time is needed if analysts are to cope with today's expanding technologies.

The acquisition process demands, and analysts produce, point estimates of the expected effects of dual sourcing. The range of possible outcomes tends not to be expressed because the people in the system aren't able or don't wish to confront the implicit uncertainty such a range implies. The actual outcomes often vary greatly from the point estimates; this further erodes the confidence of the acquisition community, and others, in cost analysis.

The Navy policy favoring use of dual sourcing in planning acquisition strategy has de-emphasized the importance of dual-source cost estimates in deciding whether or not dual source should be used. But these estimates are still important at the OSD and Congressional review levels. OSD still emphasizes use of estimates of net cost savings in reviewing dual-source production decisions. In Congress, dual sourcing is supported in law by the Competition in Contracting Act, yet in

individual programs (Phoenix, for example), it is opposed on cost or other grounds. If the Navy's dual-source strategies for acquiring weapons and aircraft are to prevail in these forums, more credible dual-source costing must be presented in a broader decision context. A candid approach in which the Navy would present cost sensitivity analyses and outline management plans to drive cost to a favorable outcome, if presented with other benefits of dual sourcing, may be more likely to succeed.

The Navy and DOD effort to gather and automate access to cost data is ill-focused and fragmented, and it does not ensure availability of the data needed. Consequently, systems command analysts frequently gather their own data. There is no central direction within the Navy to address the problem. Reporting formats other than the CCDR and CPR could possibly be used to provide better information. For example, given the reluctance of NAVSEA to obtain CCDR data, it may be that this report does not provide the best format to use in gathering ship cost data and that a new format could be designed to meet the needs of both OSD and Navy analysts. Another approach may be to evaluate the existing CPR format for reporting ship cost performance to determine whether it is, or could be modified to be, adequate for the needs of all cost analysts.

The critical need for high-quality cost estimating requires management attention to the cost data problem throughout DOD. Contractors have not been overly cooperative in providing cost data, but in today's environment of acquisition reform, DOD has the leverage to establish procedures that will get the necessary cost data on a continuing basis. The environment will probably never be better for a determined Navy/DOD effort to improve cost data reporting.

RECOMMENDATIONS

Greater emphasis should be placed on improving cost-estimating methodology. This will take a dedicated research effort apart from the day-to-day routine of the cost analysis community; the absence of any significant new estimating approaches in the past decade indicates the difficulty of the task. New ways to estimate the effects of dual-source manufacturing should be part of this effort, but it should be recognized that their foundation will be better estimates of single-source manufacturing costs. Until this fundamental problem is solved, improvements in dual-source cost techniques are unlikely.

The acquisition community should recognize more explicitly the uncertainties now inherent in estimates of the cost effects of dual-source manufacturing. This explicit recognition can lead to more appropriate techniques for making and using these estimates. Specifically, the almost total focus on point estimates should be modified. The approach needs to be broadened to consider an ensemble of scenarios depicting the potential cost outcomes of dual sourcing for each potential application. This type of analysis will provide insights into both

the cost risks inherent in the dual-source approach and the management strategies most likely to yield success. The process will require additional resources to perform the analyses and efforts to educate people to gain their understanding and acceptance. As further data become available during system/equipment development, the estimates for the various scenarios can serve as benchmarks against which actual data can be tracked. These cost tracks can provide early visibility of problems, highlighting the need for corrective action and permitting refinement of the acquisition strategy.

Cost analysts should become more intimately involved with the development and monitoring of acquisition strategies. The analysts should be aware of the strategy alternatives being debated and the rationale for the option(s) selected. It has been hypothesized that contractor motivation has a significant impact on program cost. As cost analysts become familiar with the effects of different acquisition strategies in changing contractor motivation to the government's benefit, they may develop ways to include this factor in their estimates of cost. With that understanding, they can also become an important resource to the manager of a new program as plans are developed.

The fact that some program managers do not order CCDR data may indicate that management pays too little attention to the problems of cost analysts. and their need for supporting cost data bases. The collective data needs of the Navy cost community should b researched and action taken to fill voids. Determined efforts should be made to ensure that cost data on dual-source programs are collected from program outset. Obtaining needed cost data should be a contractual requirement, removed from the discretion of either the program manager or the contractor. The leverage provided by Congressional interest should be used to set in place permanent means to obtain needed cost data from contractors.

The development of automated data bases should be pursued with top-level management attention. Automating data bases is difficult, but it is feasible (as demonstrated by NAVAIR) and the payoff will be worth the effort. Automation should receive priority at both DOD and systems command levels, in an effort integrated with reviewing the kinds of data needed by the community at large. The availability to analysts of carefully sifted historical data maintained in computerized files should make performing their estimating task more efficient.

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APPENDIX A

NAVY COST ANALYSIS ORGANIZATIONS, FUNCTIONS, AND RESOURCES

APPENDIX A

NAVY COST ANALYSIS ORGANIZATIONS, FUNCTIONS, AND RESOURCES

Four cost groups operate at the systems command headquarters and OPNAV levels. Figure A-1 lists their principal functions. The list is not intended to be complete but only to show the major tasks of cost analysis that are common across the Navy cost analysis community. As expected, the groups perform largely the same kinds of functions, although emphasis may differ from group to group, in some cases significantly. For example, the SPAWAR cost group is unique in that it primarily supports contract negotiations.

	NAVAIR	NAVSEA	SPAWAR	OPNAV
Program cost estimates supporting PPBS	P	P		
Navy independent cost estimate				P
Data base development	√	√	√	√
Contracting/proposal evaluation support	√	√	P	
Contractor performance measurement	√		√	
Models, techniques, CER development	√	√		√
Escalation indices development	√	√		
Life-cycle/design-to-cost estimates	√	√		√
Validation of pass-through estimates	√	√		√
Cost estimates supporting INSURV functions		√		
Special projects	√	√	√	√

P = Primary effort √ = Secondary effort

FIG. A-1: MAJOR FUNCTIONS OF NAVY COST ANALYSIS GROUPS

NAVAIR

The largest group is the NAVAIR Cost Analysis Division (AIR-524). It performs the full range of cost analysis and estimating functions. Its primary mission is providing unbiased program cost estimates to support the PPBS process and specifically to ensure that the cost estimates used for budget development contain enough money for the acquisition manager to execute the acquisition strategy. Secondary functions include helping NAVAIR's contracting group evaluate proposals and assisting in the cost analysis required for contract negotiations. (The NAVAIR contracting group also performs detailed cost analysis to support contract negotiations.) AIR-524 additionally can assist acquisition managers in developing design-to-cost target prices, provide system life-cycle cost estimates, and perform special tasks involving the cost analysis discipline.

Continual inquiry into new cost-estimating techniques is a necessary supporting function, and the Research, Methods, and Data Branch is part of the permanent organization. Data bases exist in various forms. An automated data system for cost analysis of aircraft programs was being loaded and tested in mid-1985.

SPAWAR

The smallest of the Navy cost groups is located in the Space and Naval Warfare Systems Command (SPAWAR-024). Most of its effort is narrowly focused on helping the SPAWAR contracts group establish the government's contract negotiating position. This support can take such forms as evaluating proposals for sole-source production and competitive development through detailed fact-finding at contractor plants. Other typical cost group tasks--such as developing data bases, models, and methodologies, and preparing estimates for PPBS input--are recognized as being within the group's mission but receive little attention because only 13 analysts are assigned to SPAWAR.

NAVSEA

The Naval Sea Systems Command's cost analysis group, SEA-017, performs largely the same functions as does NAVAIR's group, with one important exception. AIR-524 estimates costs for all systems and equipment procured by NAVAIR, but SEA-017 provides original cost estimates only for ships. Except for special cases, estimates for NAVSEA weapon systems are performed within project offices, typically by support contractors. SEA-017 then reviews each estimate, working with the project office to make any necessary adjustments, before validating it so that it becomes the official command estimate.

OPNAV

The OPNAV cost group (OP-917)[1] has the unique mission of making the Navy's independent cost estimate (ICE). It both reviews the systems commands' estimates and prepares its own estimates using a different methodology. The ICE is used for acquisition category (ACAT) I, II, and III programs in support of the decision-making process prior to major program milestones.

RESOURCES

Figure A-2 shows the numbers of analysts assigned to Navy systems commands' cost groups during the past decade. It includes their internal plans for growth in 1986. The most rapid growth in the last 5 years has occurred at NAVAIR, where the number of professional cost analysts increased from 49 in 1980 to 115 in 1985. This growth reflects the added emphasis that NAVAIR has placed on in-house cost analysis in recent years. Attention has been paid to the mix of disciplines among new professionals hired, with industrial engineers now being added to the existing base of statisticians and mathematicians.

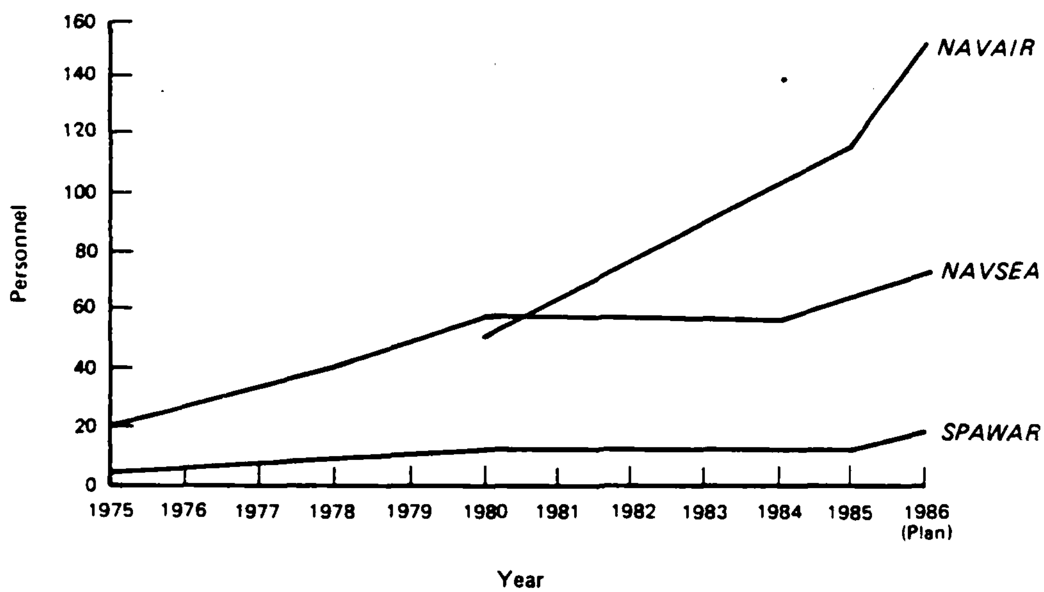

FIG. A-2: PERSONNEL ASSIGNED TO NAVY COST GROUPS

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1. On 1 October 1985, OP-917 merged with the former cost group from the Naval Material Command to form the Naval Center for Cost Analysis. This paper discusses the OPNAV cost group as it existed before then, during the time in which data were gathered for this study.

Each group uses computers for detailed estimating computations. NAVAIR is probably the most advanced in this regard, with 19 microcomputers and terminals netted to a central VAX 11780 minicomputer.

At the NAVSEA cost group, the main growth occurred in the late 1970s in response to the problems caused by low estimates and the resulting claims from shipbuilders when costs exceeded the estimates. The group grew from a ceiling of 17 analysts in 1975 to 54 in 1980, with 50 actually on board in 1984. Principal professional disciplines represented now include 28 naval architects and engineers and 10 operations research analysts.

At SPAWAR, the number of cost analysts has stayed constant at 13 since 1980; this helps to account for the narrow focus of effort in this group. Five additional analysts have been requested with the intent of increasing attention to other cost analysis functions beyond support to the contracting process.

The 16 OPNAV cost analysts are responsible for more program estimates than their counterparts in the systems commands. Their independent cost estimates are necessarily prepared in less detail than the systems commands' estimates.

Figure A-2 shows only the government employees performing the cost analysis function; an unknown number of contractor personnel (but probably larger than the total number of government analysts) similarly work directly for acquisition managers doing cost analysis, particularly in NAVSEA and SPAWAR. Also, most of the Navy RDT&E field activities have cost analysis groups. Typically, analysts there support on-site engineers and managers who in turn are assigned to specific development and acquisition programs. The NAVAIR cost group has procedures for acquiring specific cost analysis support from field activities in a formal memorandum of agreement.

END

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